Proton Testing of Optocouplers (Micropac)

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1. **Devices Tested**

Micropac supplied 38 devices for displacement damage (DD) and total ionizing dose (TID) testing using 63 MeV protons at Crocker Nuclear Laboratory. The 38 devices were divided into four groups depending on which LED/Transistor combination was used. Table 1 lists the devices tested and the components in those devices. Three devices from each group were tested.

Table I. Combinations of LED emitters and photodiode/amplifier detectors

Group #	Device #	LED	Photodiode	Transistor
1	1,2,3	10841-018 (850nm)	10641-006	10265-006 (2N2222) Sprague
2	11,12,13	10841-018 (850nm)	10641-006	10265-006 (2N2222) Semicoa
3	20,21,22	10814-007 (660nm)	10641-006	10265-006 (2N2222) Semicoa
4	30,31,32	10814-007 (660nm)	10641-006	10265-006 (2N2222) Sprague

Figure 1 shows the circuit diagram for the 66099 optocoupler. It consists of a LED that emits light at either 660nm or 850nm, a photodiode (10641-006) for detecting the light and converting it into an electrical current, and a transistor (2N2222) that acts as an amplifier. Protons produce DD in the LEDs that reduces the intensity of the emitted light. Protons also produce both DD and TID in the photodiode and the amplifier. DD in the amplifier reduces the gain whereas TID can lead to an increase in the leakage current.

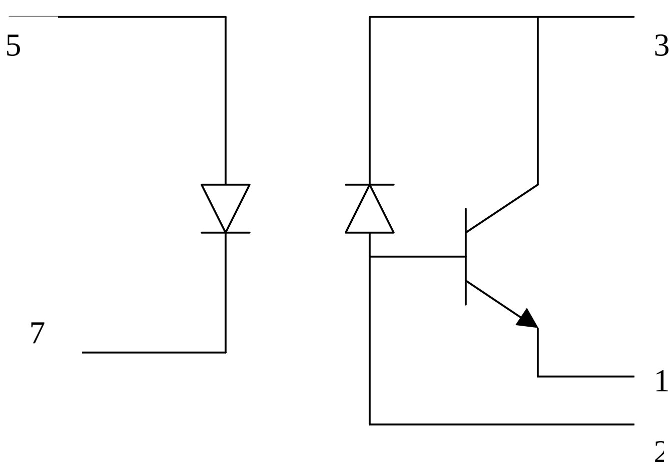


Fig. 1. Circuit Diagram for the 66099 Optocoupler from Micropac.

2. Method

The devices were not de-lidded for testing because the protons' energy was 63 MeV, giving them a range sufficient to penetrate the lids of the devices with a relatively small loss of energy. A total of 12 devices was tested, three from each group. For the proton exposures, four devices, one from each group, were mounted adjacent to each other in conducting foam and positioned in front of the exit port of the accelerator. The parts were unbiased during irradiation. The proton flux was selected to complete each irradiation in a reasonable amount of time – typically 2 minutes. Immediately after the exposure (about 5 minutes) the parts were tested electrically to determine the current transfer ratio (CTR). Table II lists the exposure levels in both fluence and equivalent TID. Only parts 1,2 and 3 were tested at the 7.45E9 level.

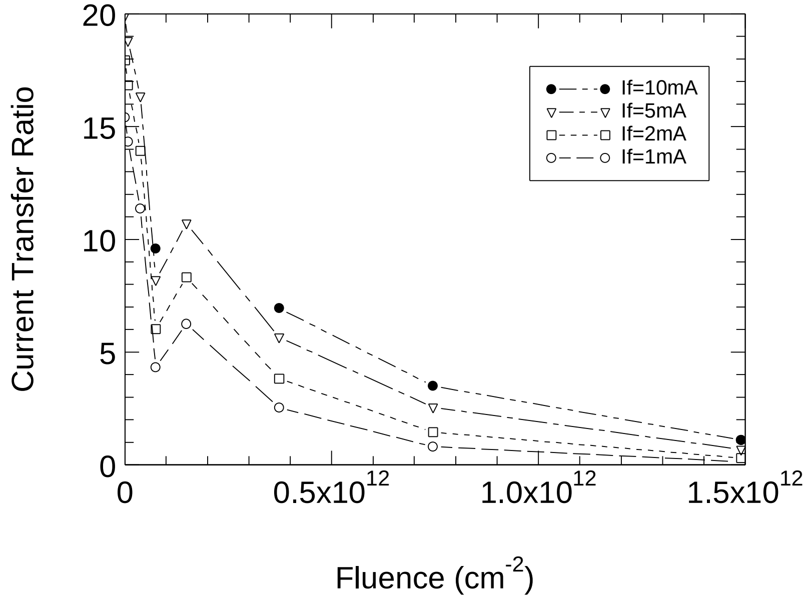
Table II. Levels of fluence and TID at which testing was done.

Fluence	**Total Ionizing Dose (krad(Si))**
0	0
7.45E9	1
3.73E10	5
7.45E10	10
1.49E11	20
3.73E11	50
7.45E11	100
1.49E12	200

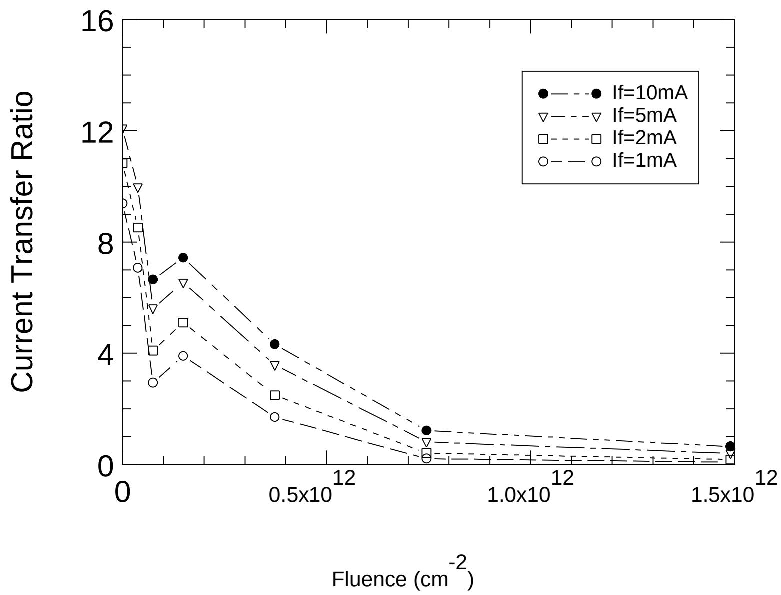
3. Results

Within 5 minutes of completing the irradiation, the current transfer ratio (CTR) was measured for a fixed set of input currents, from 1mA to 10mA. The measurements were done, one at a time, using a parameter analyzer. The CTR at input currents of 1mA, 2mA, 5mA and 10mA were plotted at a function of fluence at total dose values of 0, 1, 5, 10, 20, 50, 100, 200 krad(Si). The following figures show the CTR as a function of fluence, measured at the input currents mentioned above. In general, the CTR decreases with increasing fluence. However, some of the devices exhibited an increase in CTR at intermediate fluence levels, where the CTR actually was greater than its pre-irradiation value or its value at a previous fluence level. It is suspected that the cause is an increase in the leakage current associated with the 2N2222 transistor with dose. To confirm this, we intend to expose individual 2N2222 transistors to gamma rays in a Co60 source to see whether there is an increase in the leakage current with dose.

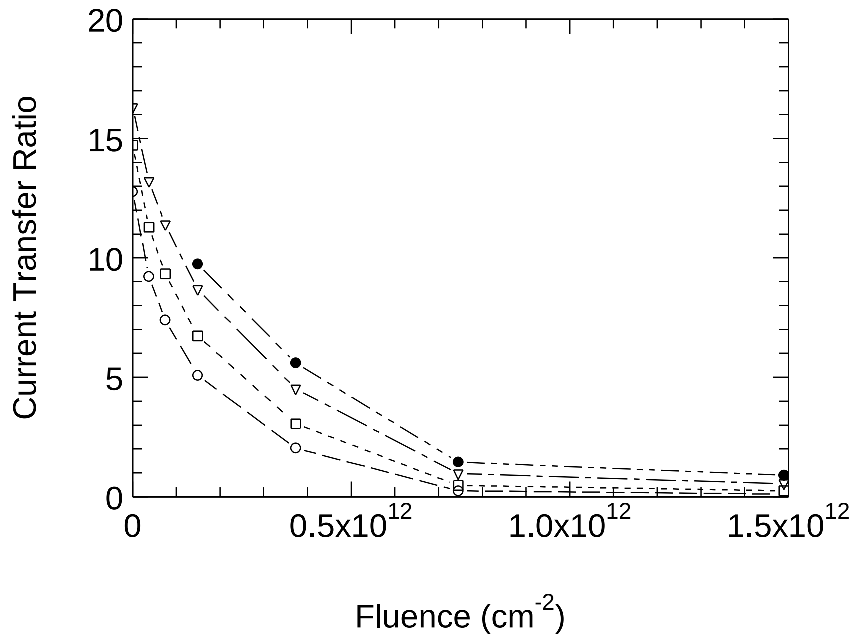
Device #1


Current Transfer Ratio
Fluence (cm-2)
If=10mA
If=5mA
If=2mA
If=1mA
0
5
10
15
20
0
0.5x10^12
1.0x10^12
1.5x10^12

#2

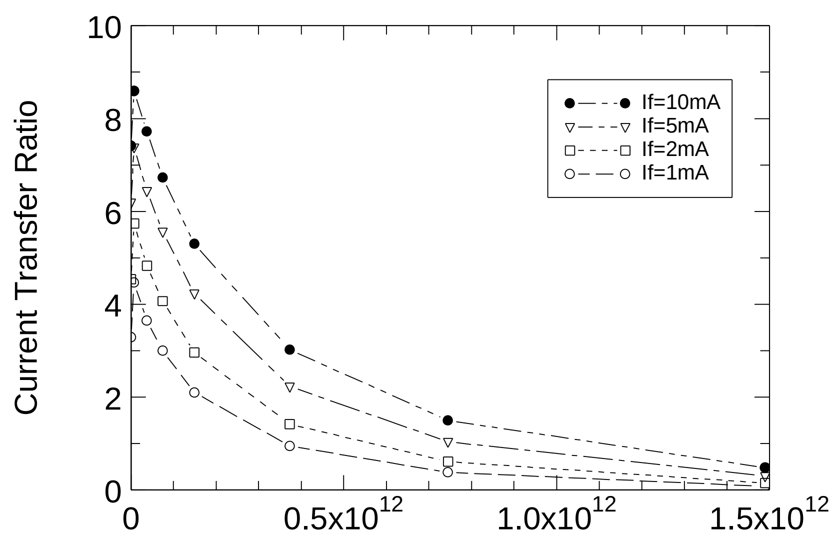

Current Transfer Ratio
Fluence (cm-2)
If=10mA
If=5mA
If=2mA
If=1mA
0
4
8
12
16
0
0.5x10^12
1.0x10^12
1.5x10^12

#3



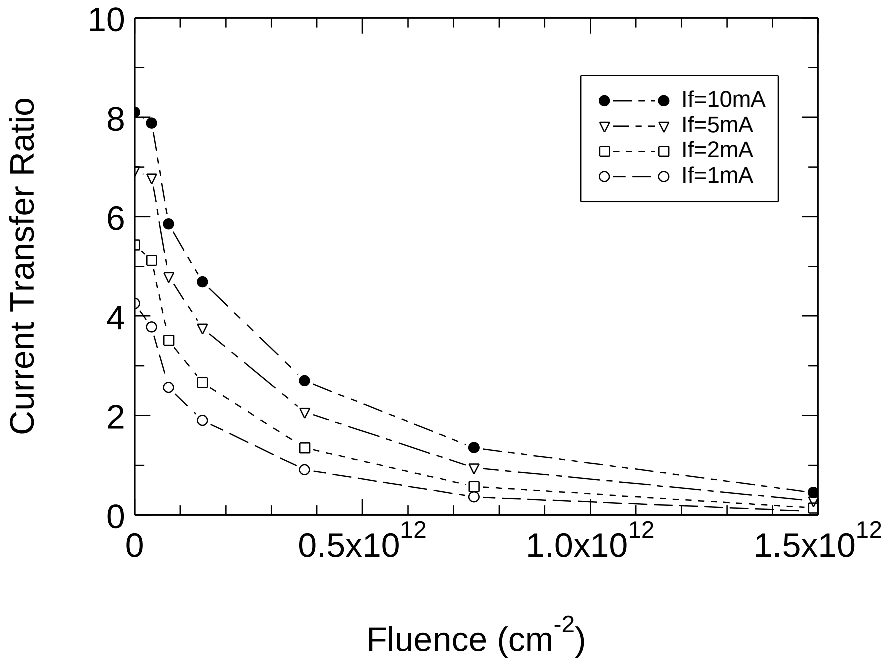
Current Transfer Ratio
20
15
10
5
0
0
0.5x10^12
1.0x10^12
1.5x10^12
Fluence (cm^-2)

#11



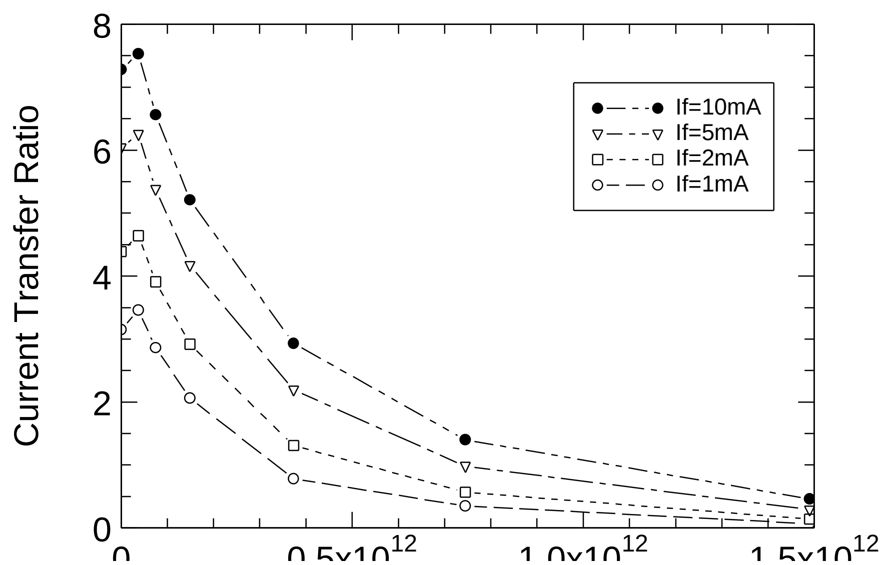
Current Transfer Ratio
10
8
6
4
2
0
0
0.5x10^12
1.0x10^12
1.5x10^12
If=10mA
If=5mA
If=2mA
If=1mA

#12



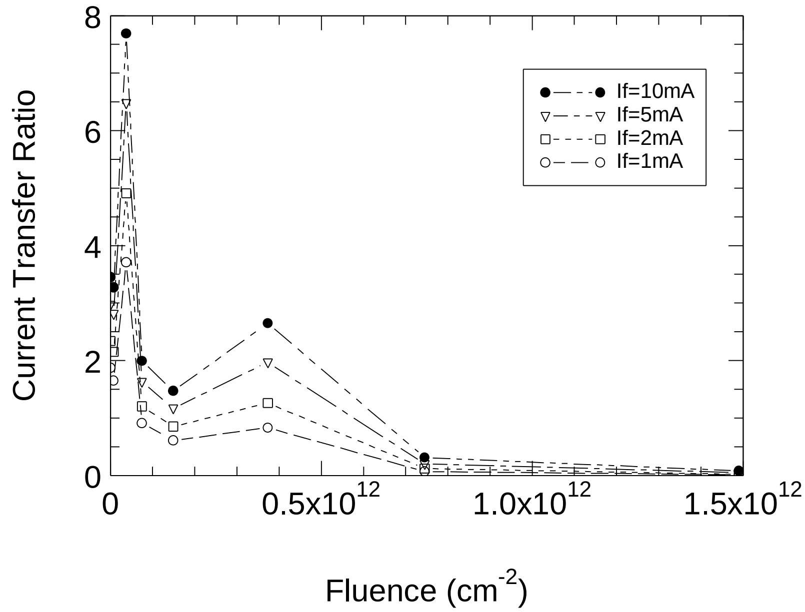
Current Transfer Ratio
10
8
6
4
2
0
If=10mA
If=5mA
If=2mA
If=1mA
0
$0.5x10^{12}$
$1.0x10^{12}$
$1.5x10^{12}$
Fluence (cm^{-2})

#13



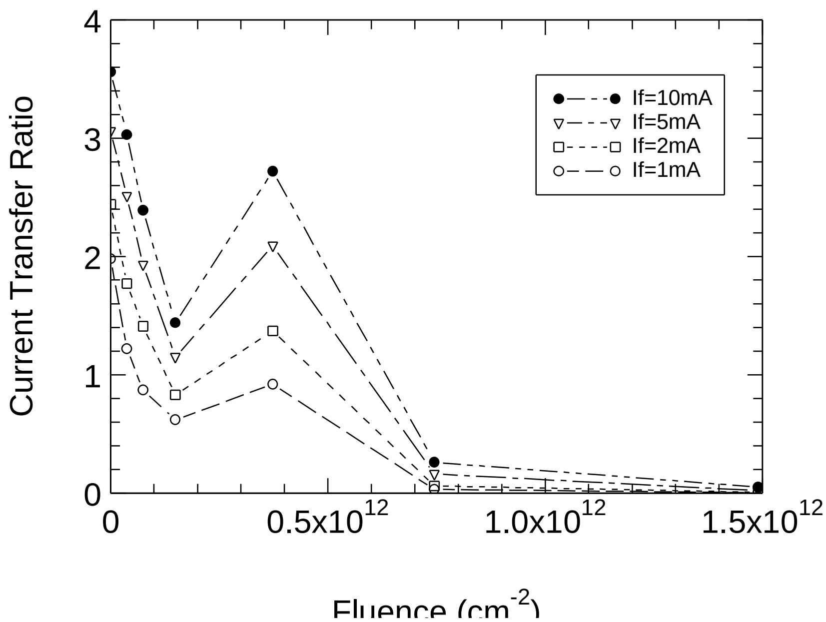
Current Transfer Ratio
8
6
4
2
0
If=10mA
If=5mA
If=2mA
If=1mA

#20

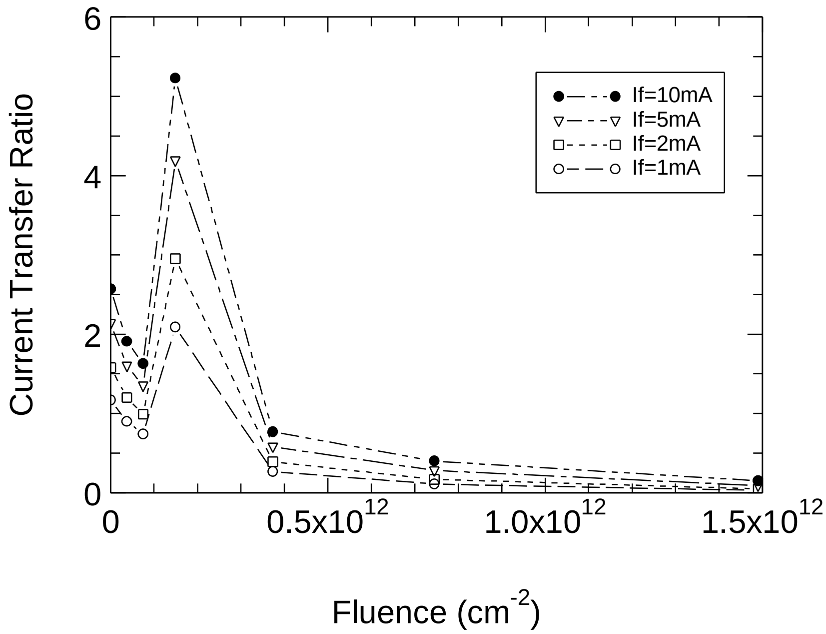


Current Transfer Ratio
8
6
4
2
0
0
0.5x10^12
1.0x10^12
1.5x10^12
Fluence (cm^-2)
If=10mA
If=5mA
If=2mA
If=1mA

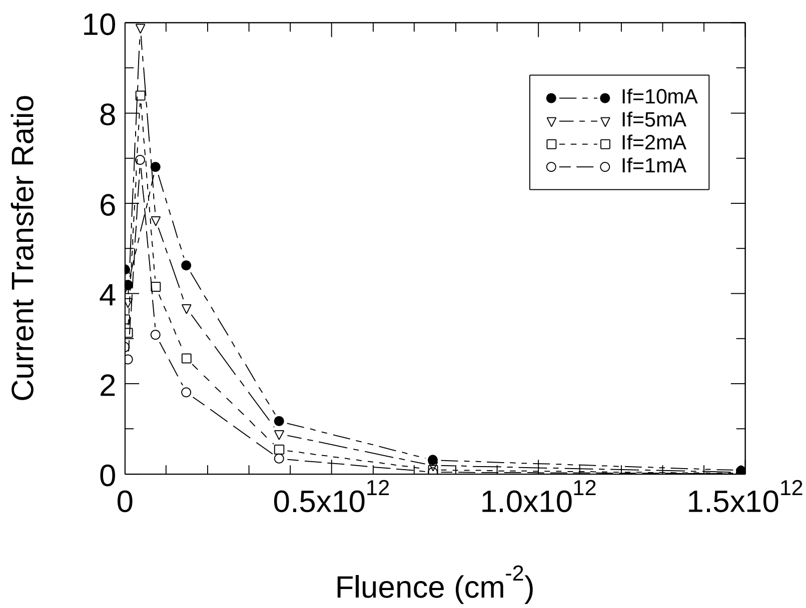
#21



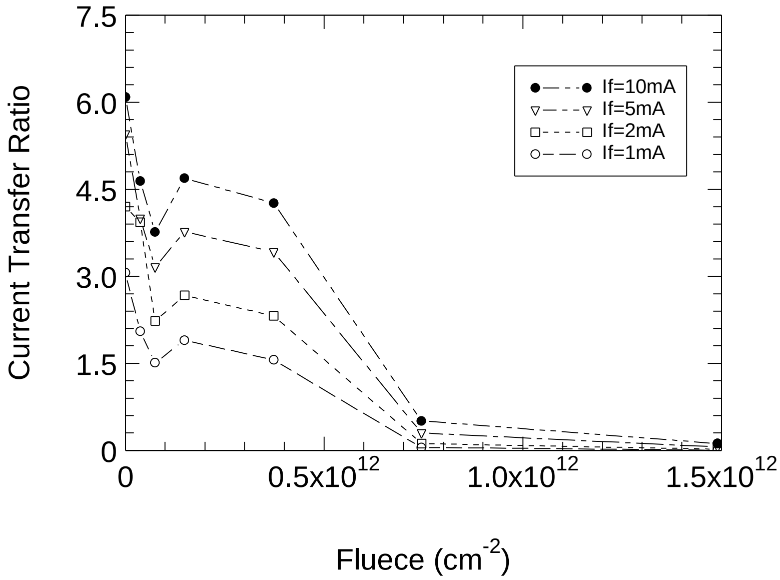
Current Transfer Ratio
4
3
2
1
0
0
0.5x10^12
1.0x10^12
1.5x10^12
Fluence (cm^-2)
If=10mA
If=5mA
If=2mA
If=1mA


6
4
2
0
0
0.5x10^12
1.0x10^12
1.5x10^12
Current Transfer Ratio
Fluence (cm^-2)
If=10mA
If=5mA
If=2mA
If=1mA

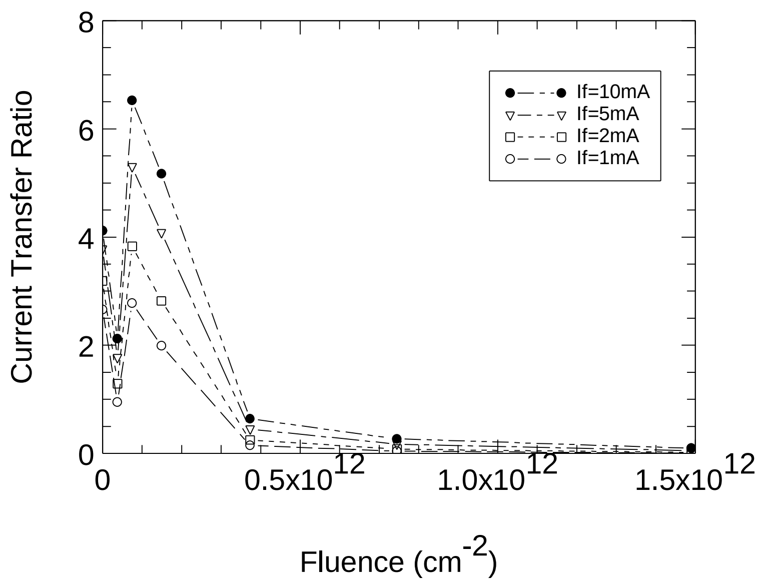
#30


10
8
6
4
2
0
0
0.5x10^12
1.0x10^12
1.5x10^12
Current Transfer Ratio
Fluence (cm^-2)
If=10mA
If=5mA
If=2mA
If=1mA

#31


Current Transfer Ratio
7.5
6.0
4.5
3.0
1.5
0
If=10mA
If=5mA
If=2mA
If=1mA
0
0.5x10^12
1.0x10^12
1.5x10^12
Fluece (cm^-2)

#32


Current Transfer Ratio
8
6
4
2
0
If=10mA
If=5mA
If=2mA
If=1mA
0
0.5x10^12
1.0x10^12
1.5x10^12
Fluence (cm^-2)